BELLCOMM, INC.

SUBJECT: General Description of Apollo Up-Data Subsystem for the CSM, LM, and SIVB/IU Case 320

DATE: December 29, 1966

FROM: W. J. Benden

ABSTRACT

A general description of the Apollo Up-Data system is presented, including the up-data flow from the Mission Control Center at Houston (MCC-H) to remote(d) sites of the MSFN, the modulation techniques, the command types, the message formats, and the sub-bit detection schemes. The character of the up-data to be sent to the CSM, developmental LM, and SIVB/IU is discussed. The Range Safety Command System is also mentioned.

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MEMORANDUM FOR FILE

I. Introduction

Up-data is the term used to describe the digital information sent from the Manned Space Flight Network (MSFN) sites on Earth to the Apollo Command Service Module (CSM), Lunar Module (LM) and the Launch Vehicle Instrument Unit (SIVB/IU). The Up-Data Link (UDL) used in Apollo to send data to the CSM, developmental LM, and SIVB/IU has evolved from the Gemini Digital Command System. Both the Gemini and the Apollo systems use digital codes in contrast to the multiple tone system used in the Mercury Project.

Project Mercury employed the command system that was used at most of the missile test facilities within the United States. In this system, an UHF carrier is frequency modulated with combinations of twenty discrete IRIG subcarrier tones. Project Mercury was restricted to use no more than thirteen tones during launch, and fifteen during orbit. These restrictions were imposed to avoid possible interference with the Range Safety operations and to avoid the poor modulation characteristics of the higher subcarrier tones (see Reference 1). As the Mercury program evolved, the command requirements steadily increased until it became evident that the Mercury command system was approaching the limit of its capability to support manned space flight. During the later Mercury flights, it was decided that the follow-on Gemini flights should use a digital command system. The digital command system, having a growth potential greater than that for the tone system, would also be able to support the Apollo missions to follow Gemini. In the same way that Mercury facilities were used as basic building blocks for Gemini, the Gemini facilities are used for supporting the Apollo missions.

Considerations of required bandwidth, existing equipment, Range Safety functions, performance margins, etc., led to the adoption of a modulation technique which utilized Phase Shift Keying (PSK), in conjunction with sub-bit coding, for digital commands[1]. In this system, digital data are used to phase shift a 2 Kc tone at a 1 Kc rate. The modulated 2 Kc tone is then summed with a 1 Kc sync tone for transmission to the space vehicle. Figure 1 depicts the limits of the primary frequency spectrum of the Gemini PSK system and the Mercury IRIG tones. The PSK modulation technique is treated in detail in later paragraphs.

This memorandum describes the following up-data characteristics for the CSM, developmental LM, and SIVB-IU:

(1) Data transmission modes in the Apollo MSFN,

(2) Modulation methods,

(3) Types of commands and their format,

(4) Data flow and detection onboard the CSM, LM, and SIVB/IU.

In order to keep the size of the memorandum tractable, only the basic elements of the up-data system are discussed. It should be noted that the communication system for the operational LM does not have an up-data capability, although it is now being discussed for possible LM computer up dates.

II. Basic Data Flow - MCC-H to MSFN Sites

The following paragraphs cover command data flow in a cursory manner with the intention of providing the reader with a general understanding. For a more detailed description, the reader is referred to References 2 and 8.

The Apollo space vehicle(s) receives commands from the MSFN by the MCC-H operating in conjunction with either "remote" or "remoted" sites. The remote MSFN site, having Flight Controllers, has the capability of initiating commands to the space vehicle as well as relaying commands from MCC-H, whereas at a remoted site, command initiation is accomplished at MCC-H only. However, it should be noted that, in an emergency, a remoted site could send commands as at a remote site through the use of operating personnel at the site. From the preceding it is seen that two basic modes (see Figure 2) exist between MCC-H and the MSFN sites, namely (1) the command up-linking initiate capability is performed at the site, and (2) the command up-linking initiate is performed at MCC-H

The commands required by the space vehicle(s) can be divided into two major categories, i.e., Real Time Commands (RTC's) for controlling "on" and "off" functions, and space vehicle computer up-dating commands. The RTC's are stored at the MSFN sites whereas vehicle up-dating data originates at MCC-H. It should be noted that only the unique portions of the up-dating words are sent from MCC-H. For example, the on-site computer adds such items as vehicle and system addresses during the processing of the received data into the proper format for transmission to the space vehicle.

Figure 3 illustrates data flow at a remote site. The Command Data Processor (642-B) computer, upon receipt of the correct site address on a message from MCC-H, proceeds with data validation by checking the error coding and word structure. Upon validation, the site stores the information and notifies MCC-H that a correct transmission has been accomplished. The validation messages to MCC-H are called CAP's (Computer Acceptance Pattern). Command loads, which are stored in computer memory, are also recorded on magnetic tape. Thus, if a command should become invalid for any reason after storage in the memory, it can be re-written into memory as if it came from MCC-H.[8]

The Console Computer Interface Adapter (CCIA) functions as the interface between the Consoles, Up-Data Buffer, and the 642-B. The Up-Data Buffer serves as an interface between the up-data subcarrier oscillator, radio transmitting equipment, and the 642-B computer[2,8].

Operationally, after a command word has been encoded in sub-bits, the 642-B supplies the command word, 30 bits at a time, to the up-data buffer. However, only 25 sub-bits (5 information bits) of this word are actually a portion of the command word since 5 bits are carried along for control purposes. The buffer stores these data bits and at the proper time modulates an audio tone which is later summed with a synchronizing tone and the composite used to modulate the up-data subcarrier oscillator. The up-data buffer also demodulates data from the monitor receiver, and performs switching operations between modulators, demodulators, and RF equipment. After demodulating the information supplied by the monitor receiver it provides these data (which should be replicas of the data bits transmitted to the spacecraft) to the 642-B for verification processing. It should be noted that if a sub-bit error is detected, the feed-back link via the monitor receiver and up-data buffer is first checked for errors before a decision is made to terminate the up-data transmission.

III. Modulation Methods

During early Apollo test missions involving the Block I CSM, LM (LMs I, and II), and the SIVB/IU on up rated Saturn I launch vehicles, up-data commands will be transmitted by frequency modulating an UHF (450 mc) carrier. During later Apollo missions, the UHF equipment will be eliminated and the Unified S-Band System utilized except for Command Destruct system on the launch vehicle. As noted before, the operational LM will not be provided with an up-data link. Instead, up-dating in the LM will be accomplished by the astronauts in accordance with voice instruction.

When the USB system is used for transmitting up-data to the SIVB/IU and the CSM, a 70 Kc subcarrier is frequency modulated with the up-data information and the subcarrier, in turn, used to phase modulate the main S-Band carrier, (2106.4mc for the CSM and 2101.8mc for the SIVB/IU).

IV. Command and Up-Data Types

This section summarizes the type of Commands and Up-Data transmitted from the Apollo MSFN to the CSM, to the developmental LM, and to the SIVB/IU. Later sections treat these commands in greater detail.

A. MSFN to CSM. Four basic types of up-data messages are transmitted to the CSM from the Apollo MSFN, namely:

1. Real Time Commands (RTC) to turn spacecraft equipment on and off and to change operating modes (e.g., transmitter high power to low power).

2. Up-dating information for the Apollo Guidance Computer (AGC). This information is used to bring the spacecraft computer up to date in accordance with the new information developed at the Control Center as a mission continues.

3. Up-dating information for the time accumulator in the Central Timing Equipment (CTE). The message contains units of time in seconds, minutes, hours, and days.

4. Test Messages (T/M) to obtain a self-check on the spacecraft digital equipment.

B. MSFN to LM. The LM's to be used in development flights in earth orbit, namely LM I, and LM II will have up-dating capabilities from the MSFN over an UHF communication link. For other LM's, however, up-dating will be accomplished by the astronauts on the basis of voice instruction and not by sending up-data from the Apollo MSFN.

Four types of up-data messages are transmitted to the developmental LM from the Apollo MSFN. These are:

1. Real Time Commands (RTC) for turning LM equipment on and off.

2. Up-dating information for the LM Guidance Computer (LGC).

3. Up-dating information for the Program Reader Assembly (PRA). The PRA words provide commands to the PRA, which is an electro-mechanical device that processes externally stored (16-level pre-punched tape) information into command words for LM subsystems. (LM 1 only)

4. Test Message (T/M) for a self check of the digital equipment in the LM.

C. MSFN to SIVB/IU. The Saturn vehicles carry two different types of command systems; one for data transmission to the Instrument Unit (IU) and one for range safety. Present plans (Reference 3) call for the Launch Vehicle Digital Adapter (LVDA) contained within the IU to be capable of receiving the following messages:

1. Up-data for the Launch Vehicle Digital Computer (LVDC)

2. Execute Up-Date

3. Enter Switch Selector Mode

4. Enter Closed Loop Test

5. Execute subroutine command (e.g., telemeter flight control measurements)

6. Memory sector dump

7. Telemeter single memory address.

The Range Safety Command System, which is switched off when range safety confirms a successful SIVB orbit insertion, provides a means of terminating the flight if a malfunction occurs. A tone command system (AN/DRW-13) was installed on earlier flights of the Saturn I. The three range safety commands associated with this system are:

1. Arm/Fuel Cutoff - arming of the exploding bridge wire and thrust termination

2. Destruct - firing the exploding bridge wire. (Propellant Dispersion Command)

3. Safe - command system switched off.

The Range Safety Command System has been replaced in later up-rated Saturn I and Saturn V missions with the Secure Range Safety Command system. The system provides a high degree of protection against both intentional interrogation and unintentional interrogation by noise.

The message transmitted to the launch vehicle is made up of 11 characters. The address portion requires 9 of these characters, and the function to be commanded requires 2 characters. Each character consists of two simultaneous audio tones chosen from a symbol alphabet of 7 tones; this provides an alphabet of 21 characters. The security of the message is realized by noting the many combinations for the address portion of the message. For the first character there are 21 combinations; the second character - 20; the third - 19, etc. Thus, it is seen that there are (21)(20)(19)(18)(17)(16)(15)(14)(13) possible address codes.

The function word, being 2 characters in length has (21)(20) or 420 character/position code possibilities. Since only 5 functions are required, the codes are arranged so that a maximum word difference exists between them which provides a high degree of security against command translations.

The types of commands which are transmitted in this system are:

1. Destruct - propellant dispersion

2. Arm/Fuel Cutoff - arming of the exploding bridge wire firing unit and thrust termination

3. Manual Sustainer Cut-off (MSCO)/Automatic Sustainer Cut-off (ASCO) - Saturn spare No. 1

4. Spare - No. 2

5. Safe - command system switched off.

It should be noted that the SAFE command is planned only for the S-IVB stage of both the up-rated Saturn I and Saturn V vehicles and that the system cannot be reactivated once this command is transmitted. In addition, the address and command function codes are the same for all launch vehicle stages.

V. Modulation Techniques

The modulation techniques used by the MSFN for up-data transmission are the same for the CSM, LM and SIVB/IU. A stable 1 Kc tone is generated in a modulator and used as a synchronizing ("sync" or "clock") signal. A coherent 2 Kc tone is then bi-phase modulated with a 1 Kbps digital signal. A binary "one" is transmitted when the 2 Kc tone is in phase with the 1 Kc sync tone and when the 1 Kc sync tone is crossing zero with a positive slope. Figure 4 illustrates the modulation techniques utilized by the ground station. In Figure 4-A, a binary "zero" is transmitted as the inverse of the binary "one" (180° phase difference). The 1 Kc sync tone and the modulated 2 Kc tone are algebraically summed yielding the composite waveform indicated on Figure 4-C. Since this is a non-return to zero system, there is no time interval ("dead time") between bits, the individual period synchronization is obtained from the 1 Kc sync tone onboard the spacecraft.

It should be noted that the peak voltage of the composite waveform, shown in Figure 4, is not twice the value of a single sinnsoid. Although the amplitudes are equal, the phase and frequency relationship produce a peak value of 1.76 times a single tone amplitude.

Sub-bit encoding on a ratio of five-sub-bits for one information bit is used for up-data transmissions. Thus, the basic information transfer rate is 200 bits per second.* The spacecraft must detect five bits in a predetermined pattern to establish whether an information binary "one" or "zero" was transmitted. These sub-bit patterns are chosen for optimum differentiation between information "ones" and "zeros". The specifications for the CSM, LM, and SIVB/IU up-data systems require that no more than one correct message in a thousand be rejected and that the probability of accepting a false message be lower than 10^{-9}.

VI. CSM Up-Data Message Format

The message format used for the Apollo CSM Up-data link (UDL) is similar to that used in the Gemini program. The general format and types of messages used are depicted in Table 1.[4] It should be noted that the number of bits shown represent the number of information bits transmitted and that each one of these information bits represents the transmission of 5 sub-bits at a 1 kbs rate. A particular sub-bit pattern (5 bits) is selected to represent an information logical "one" and the complement of this pattern is selected to represent the information logical "zero". Messages are similar in that each message consists of a 3 bit vehicle address (15 sub-bits), a three bit system address, and a data word. The sub-bit pattern selected for the vehicle address, however, is different than that used for the remaining portion of the message. This technique assures non-correlation between the vehicle identification and vehicle data, thereby preventing false starts of a non-addressed system.

Table 2 lists the real time commands associated with Apollo spacecrafts 011, 017, and 020 in the unmanned configuration. Table 3 lists the commands presently defined for spacecrafts 008 (thermal vacuum S/C), and 012, which are manned configurations[4,5].

VII. CSM Up-Data Detection

The Block I CSM Up-Data Equipment receives a modulated r-f carrier operating at either UHF or S-Band, verifies the data, determines the system for which it was intended and

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*Excluding filler bits and required dead time between messages directs it to that system. Both the UHF receiver and the S-Band transponder heterodyne the incoming r-f signal to a 10 mc i-f through a double conversion process. The composite audio up-data signal being carried by the 10 mc i-f, in the UHF receiver, is detected by a Foster-Seeley type discriminator.[6] The 10 mc i-f in the S-Band transponder, however, contains a 70 kc subcarrier which has been frequency modulated with up-data. The 70 kc subcarrier is extracted from i-f signal (by the wide band phase demodulator) and the composite audio up-data detected by a 70 kc discriminator. After passing through the discriminators the technique for sub-bit detection is the same for both UHF and S-Band transmissions. Figure 5 illustrates the basic up-data detection scheme utilized in the CSM and data distribution after decoding. The incorporation of Block II S-Band excludes the UHF equipment.

Bit Detection. Since the sub-bit code used for the vehicle address is different from the remaining portion of the message it acts as a "sign post" indicating the beginning of an up-data transmission. Of course, the successful reception of an up-data message depends on the correct detection of each sub-bit from the composite audio signal. Since a sub-bit binary "one" or "zero" is represented by the phase shift keying of a 2 kc tone the sampling periods must be timed precisely so that the correct interpretation of a sub-bit being a logical "one" or "zero" is accomplished. This precise timing or phase reference is provided by the 1 kc clock signal transmitted from the Apollo MSFN.

Figure 6 illustrates the technique used in the CSM to separate the clock (or sync) signal from the up-data composite signal and how it is used as a phase reference for sub-bit detection. In Figure 6 it is seen that the composite audio signal at the output of the discriminator is fed into two different phase detectors. The lower phase detector compares the composite waveform with a 1 Kc reference signal derived from the Voltage Controlled Oscillator (VCO). The VCO output, operating at 4 Kc is divided by 2 in the first flip flop and by 2 again in the second flip flop yielding a 1 Kc reference signal which is 90° out of phase (product detection) with the 1 Kc sync portion of the incoming discriminator signal. The loop (consisting of the phase detector, loop filter, VCO, and flip flop dividers), phase locks onto the 1 Kc sync signal which provides the necessary phase reference for modulation detection in the upper detector circuit.

The latter phase detector compares the 2 Kc portion of the composite waveform with a 2 Kc reference signal coming from the first (divide by 2) flip flop. When the reference signal is in phase with the 2 Kc component of the input (with a positive slope at the zero crossing) a logic "one" will be sent out of the detector. When the input is out of phase with the 2 Kc reference a logic "zero" is sent. The gating circuitry and one shot multivibrators control the integration, dump and sampling periods. The flip flop being fed by the matched filter output is the first stage of the sub-bit register.

Each group of five sub-bits is shifted into the sub-bit register where they are sampled in parallel form and the appropriate information binary "one" or "zero" determined. Information bits are then sent to the main bit register. After checking the first three stages in the main bit register, the vehicle address is verified and the remaining data is processed to the appropriate system in accordance to the next three bits which constitute the system address.

<u>CSM Real Time Command (RTC) Word Process</u>* The system address portion of a RTC message selects one of two relay banks and the binary word represented by information bits 7 through 10 causes one of 16 select lines to be grounded. The remaining portion of the RTC message - information bits 11 and 12 - selects a "set" or "reset" line and in doing so causes a 28 vdc pulse to occur for 30 milliseconds. Thus, any one of 64 discrete commands can be executed by the CSM Up-Data Link Equipment (UDLE).

<u>CSM Apollo Guidance Computer Word Process</u> After checking the vehicle address and system address, the remaining 16 bits are shifted into the UDLE at 200 bits per second. The computer word is then shifted serially into the AGC at 1000 bits per second.

<u>CSM Central Timing Equipment Word Process</u> Upon receipt of a valid CTE system address (after checking the vehicle address), the UDLE generates 20 to 25 pulses having 50 microsecond pulse widths at 200 pulses per second for the purpose of <u>resetting</u> the CTE time accumulator to 0 days, 0 hours, 0 minutes, and 0 seconds.

At the end of message receipt, a series of 50 microsecond pulses occur at 10 kilopulses per second for CTE updating in the following sequence:

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*Refer to Table 4 for formats.

(1) Seconds

(2) Minutes

(3) Hours

(4) Days

The number of pulses generated for each unit of time (except for reset pulses) is equal to the decimal equivalent of a six bit binary word. For example: if the six bit binary word was 1 1 0 0 1 0 (the least significant bit being at the extreme left), the number of pulses to be generated would be 19.

CSM Test Message Process Two test messages, "A" and "B", are transmitted to the CSM in order to exercise all process, transfer and program control logic within the CSM Up-Data Link Equipment. The results of these tests are telemetered by sending unique validity signals for these test messages.

After the three bit vehicle address and 3 bit system address have been verified, the remaining bits of test message "A" - 7 through 30 - are shifted into the UDL serially at 200 bits per second. Test message "B" is handled in the same manner.

CSM Message Acceptance. When the CSM receives a valid command transmission, a message acceptance pattern (MAP) is sent to the telemetry equipment. If a MAP is not received at the MSFN in a predetermined length of time, the command word can be retransmitted a preselected number of times before alarming the flight controller that a valid data transfer cannot be accomplished. For computer up-dating the message is repeated back via telemetry to the station for verification. After verification an execute command is transmitted to the spacecraft.

VIII. LM Up-Data Message Format

The UHF Up-Data link used in LM I and LM II is similar to that previously discussed for the CSM. The up-link conveys Real Time Commands (RTC), LM Guidance Computer (LGC) messages, Program Reader Assembly (PRA) messages, and Test Messages (T/M) for self checking of onboard digital equipments whose formats are illustrated in Table 4. Notice that all messages contain 3 bits for the vehicle address and three bits for system addresses.

The Real Time Commands consist of 12 sub-bit encoded information bits, six of which are data bits. These six data bits are used to open and close 32 latching relays onboard the LM (64 discrete commands). The LM Guidance Computer (LGC) words, being 22 bits in length, contain 16 data bits (including an overflow bit) for computer up-dating. Likewise, the Program Reader Assembly (PRA) messages are made up of 22 information bits, six of which are utilized for vehicle and system address bits. The remaining 16 bits include six data bits, one bit each for Search, Forward, Reverse, and Command Initiate, and six filler bits that are all zeros. The PRA words provide commands to the Program Reader Assembly. The PRA is an electro-mechanical device that processes internally stored (16-level prepunched tape) information into command words and issues them in an orderly, prescribed sequence to the LM system. The Test Message format is similar to that previously shown for the CSM. However, notice that the message length is 22 bits instead of 30. Table 5 lists the RTC functions associated with LM I and LM II. (See Reference 7.)

IX. Basic LM Up-Data Detection

The basic LM up-data detection scheme is the same as that previously discussed for the CSM. Also, like the CSM, a message acceptance pattern is sent to the LM telemetry equipment when a command is correctly received.

X. SIVB/IU Up-Data Word Format

Present plans call for seven different types of up-data messages to be transmitted to the SIVB/IU from the MSFN (see Reference 3). These are as follows:

(1) Up-data to digital computer

(2) Execute up-date

(3) Enter Switch Selector Mode

(4) Enter closed-loop tests

(5) Execute subroutine command (e.g., telemeter flight control measurements

(6) Memory sector dump

(7) Telemeter single memory address

The command word is always 35 bits in length and is sub-bit encoded - five bits to represent an information binary "one" or "zero" thus, the total sub-bit word length is 175 bits. As in the case of the CSM up-data format, the first three information bits represent the vehicle address, however, the remaining portion of the word is less straight forward. Table 6 shows how data and address bits are interlaced. A message may consist of one or more 35 bit words as will become evident in the succeeding paragraphs.

The type of command being transmitted is determined by the first 35 bit word of the message and this word is designated as a mode command word. The most significant six bits of the 13 data bits (shown on Table 6) determine which of the seven types of messages is being transmitted. The next six bits are the complement of the first six bits (used for checking purposes) and the last bit (total of 13) is not used. For computer up-dating the words which follow the mode command must be in groups of four. As many as 10 groups of four data command words may follow the mode command word to complete one command of computer up-dating. Commands two, four, and five require only one word for a message transmission, a mode command. Commands three and six require three words whereas command seven requires the transmission of five words.

XI. Basic SIVB/IU Up-Data Detection

The SIVB/IU digital Up-Data Equipment (UDE) receives data from the MSFN via UHF or Command and Communications System (CCS), verified it, determines the system for which it was intended and directs it to that system. It should be noted that UHF communications pertain to the AS-200 series vehicles, whereas the CCS Command and Communication System will be used for the AS-500 missions. Figure 7 illustrates the progress of the up-data signal through the S-Band transponder into the digital equipments. The receiver heterodynes the incoming r-f signal (double conversion process) providing a 10 mc i-f signal. The composite up-data signal is extracted from the i-f and fed into the sub-bit detector in the command decoder.

Sub-Bit Detection Figure 8 depicts the basic demodulation scheme utilized for sub-bit detection in the SIVB/IU. Notice that the technique used is different from that previously shown for the CSM. The narrow band 1 Kc filter separates the 1 Kc sync tone from the composite input waveform, and after being reshaped triggers a one shot multivibrator. The one shot multivibrator provides a narrow sampling pulse for AND gates (A_1 and A_2) at a 1 Kc repetition rate. In a similar manner, the 2 Kc filter separates the modulated signal from the 1 Kc sync tone. After being reshaped, it is fed to the sub-bit AND gate (A_2) and to an inverter. When the 2 Kc waveform is positive and time coincident with 1 Kc sampling pulse, the A_2 AND gate will produce an output which fires the following one shot multivibrator. The one shot output is the sub-bit binary "one". Conversely, when the inverter output is positive and in time coincidence with the sampling pulse a sub-bit signal is produced at the output corresponding to a binary "zero". The sub-bits are then passed into shift registers where each sequential five sub-bits represent an information binary one or zero in accordance with a predetermined pattern. After the message has been checked an acceptance message is transmitted to the MSFN via the PCM telemetry equipment.

SIVB/IU Message Acceptance When the IU establishes that the 14-bit address is correct, an address verification pulse is sent to telemetry. At the ground station it is decommutated in real time and sent to the message acceptance pulse circuits. A second pulse is generated and sent to telemetry when the LVDC has received the 18 information bits correctly. At the ground station, the address verification pulse triggers a 200 millisecond one shot multivibrator and a short time later the LVDC pulse will trigger a 10 millisecond one shot multivibrator. The two one shot outputs drive an AND gate in the message acceptance circuitry. When the 10 ms pulse occurs during the 200 ms period a Message Acceptance Pulse (MAP) is sent to the data processing computer. The data processing computer, uses this MAP as a "next message transmit" pulse.

Since the LVDC up-dating commands are considered more critical than the other commands, a "repeat-back" scheme is utilized. The LVDC stores all LVDC up-date messages (as many as forty 18-bit groups) and non-destructively reads out these data bits to telemetry. The ground station compares these data bits with the originally transmitted data bits. Upon verification, an "execute up-date" command is sent to the data processing computer and thence to the vehicle. The LVDC will then act on the computer up-dating messages.

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Attachments
Tables 1-6
Figures 1-8

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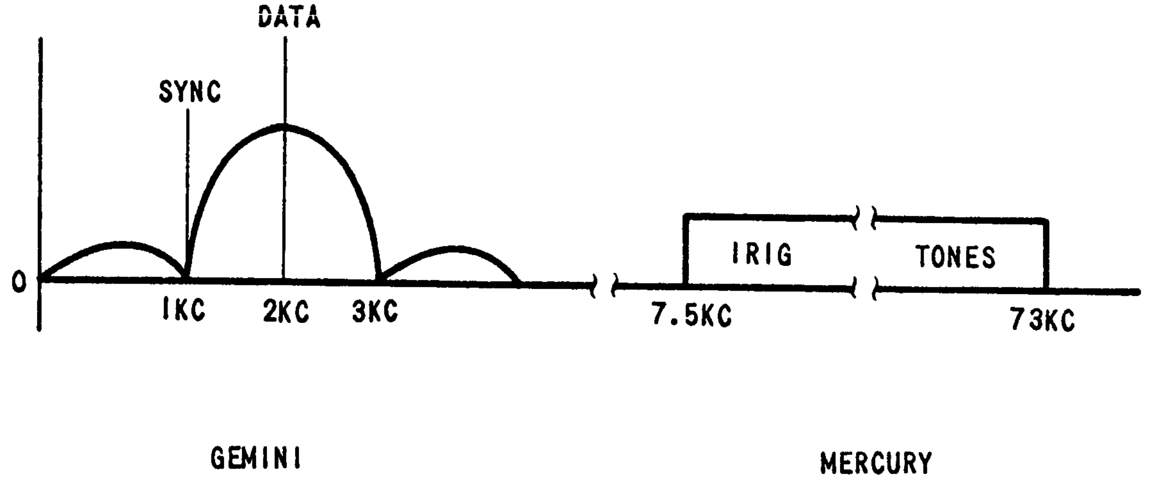

FIGURE I SPECTRUM OF GEMINI AND MERCURY UP-DATA LINKS

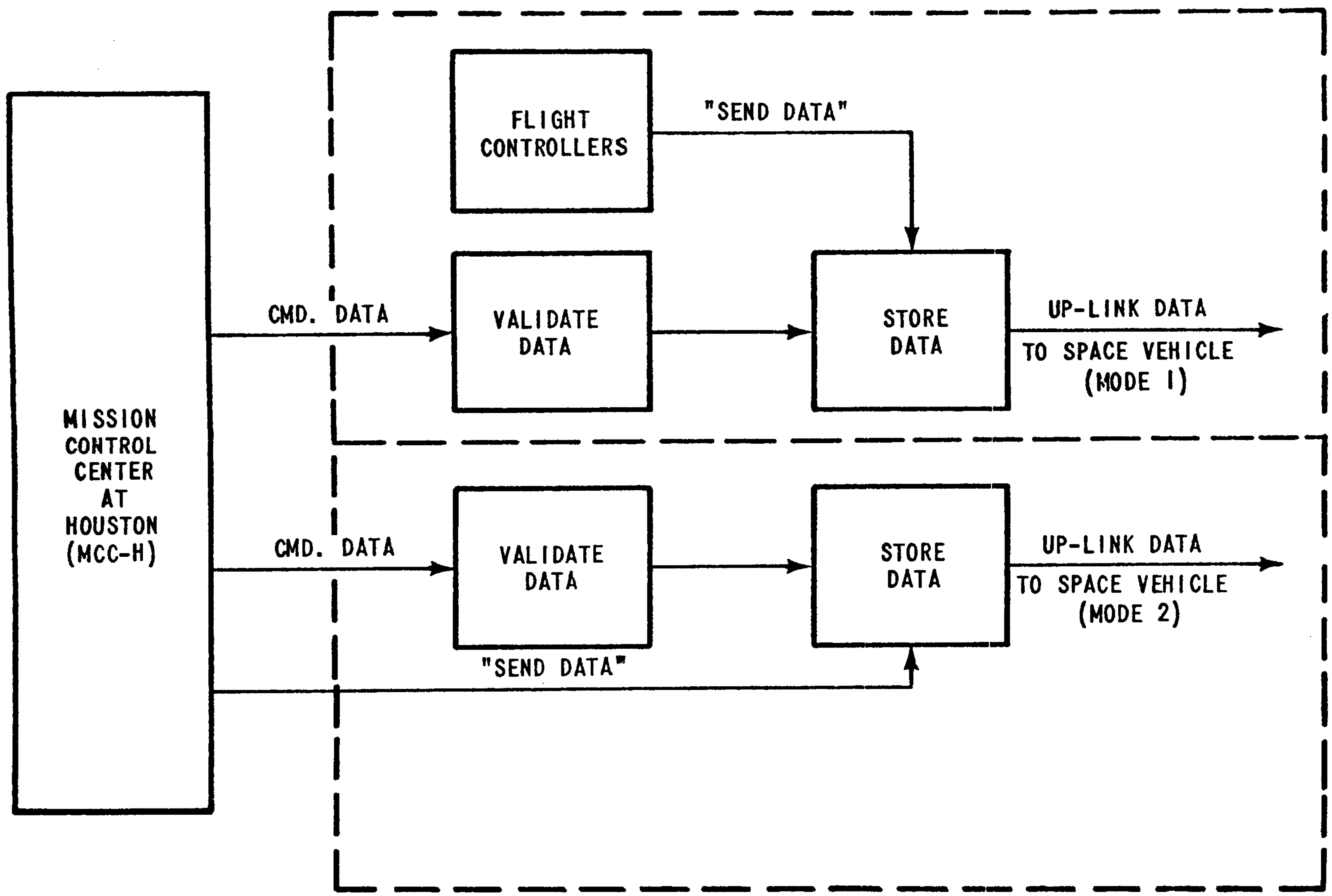

FIGURE 2 BASIC MODES OF APOLLO UP-DATA SYSTEM

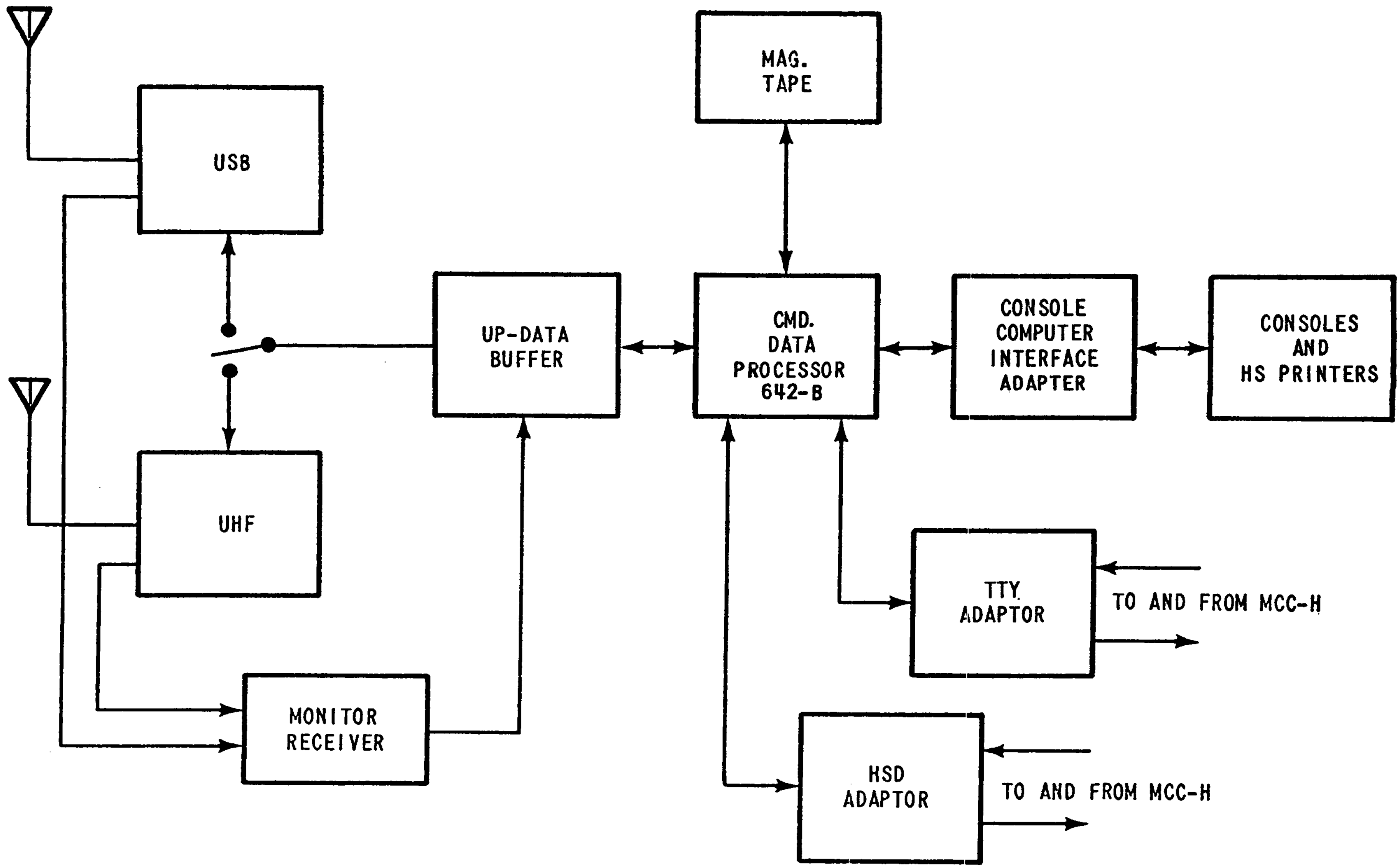

FIGURE 3 - BASIC COMMAND DATA FLOW - REMOTE SITE

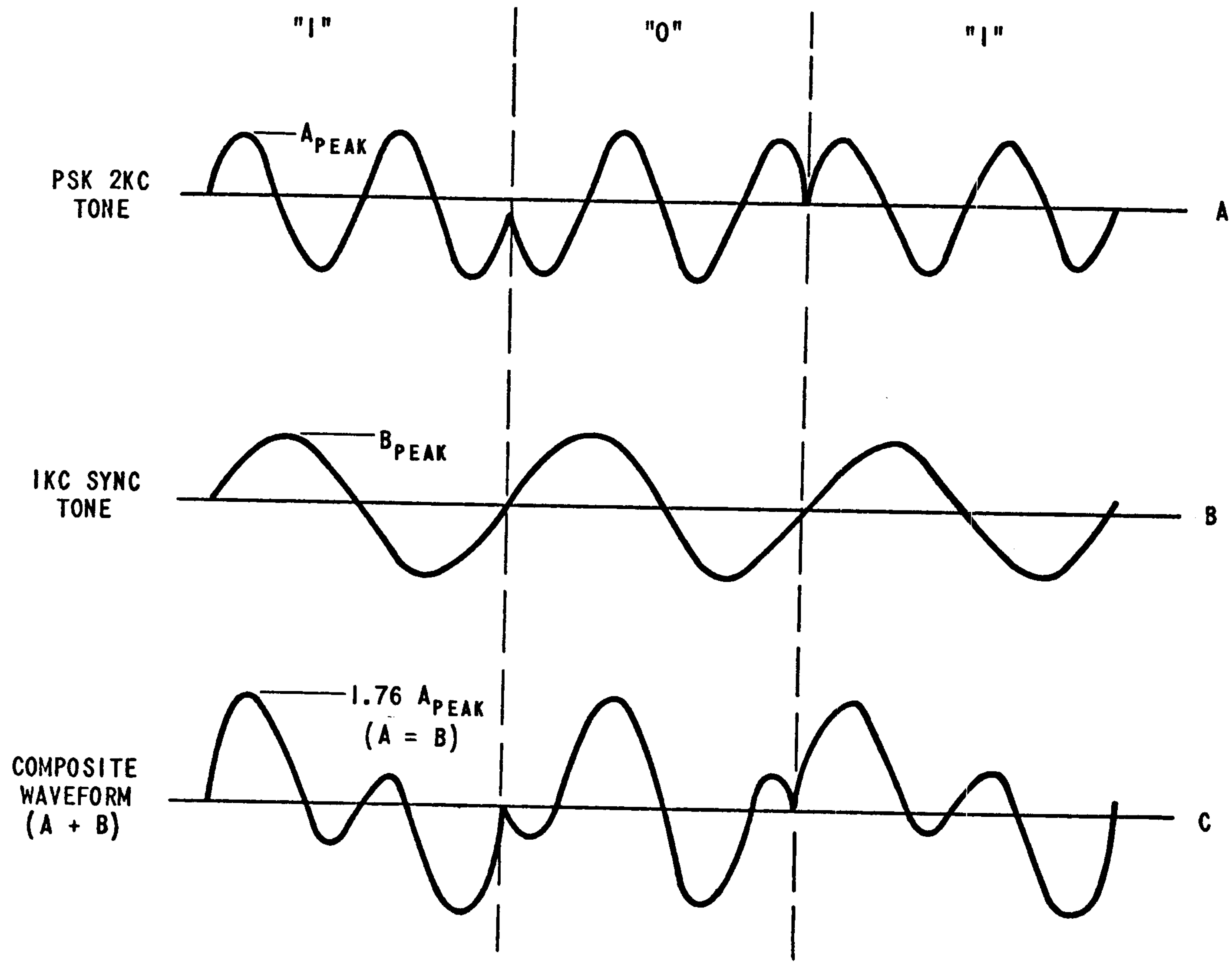

FIGURE 4 DERIVATION OF COMPOSITE UP-DATA WAVEFORM

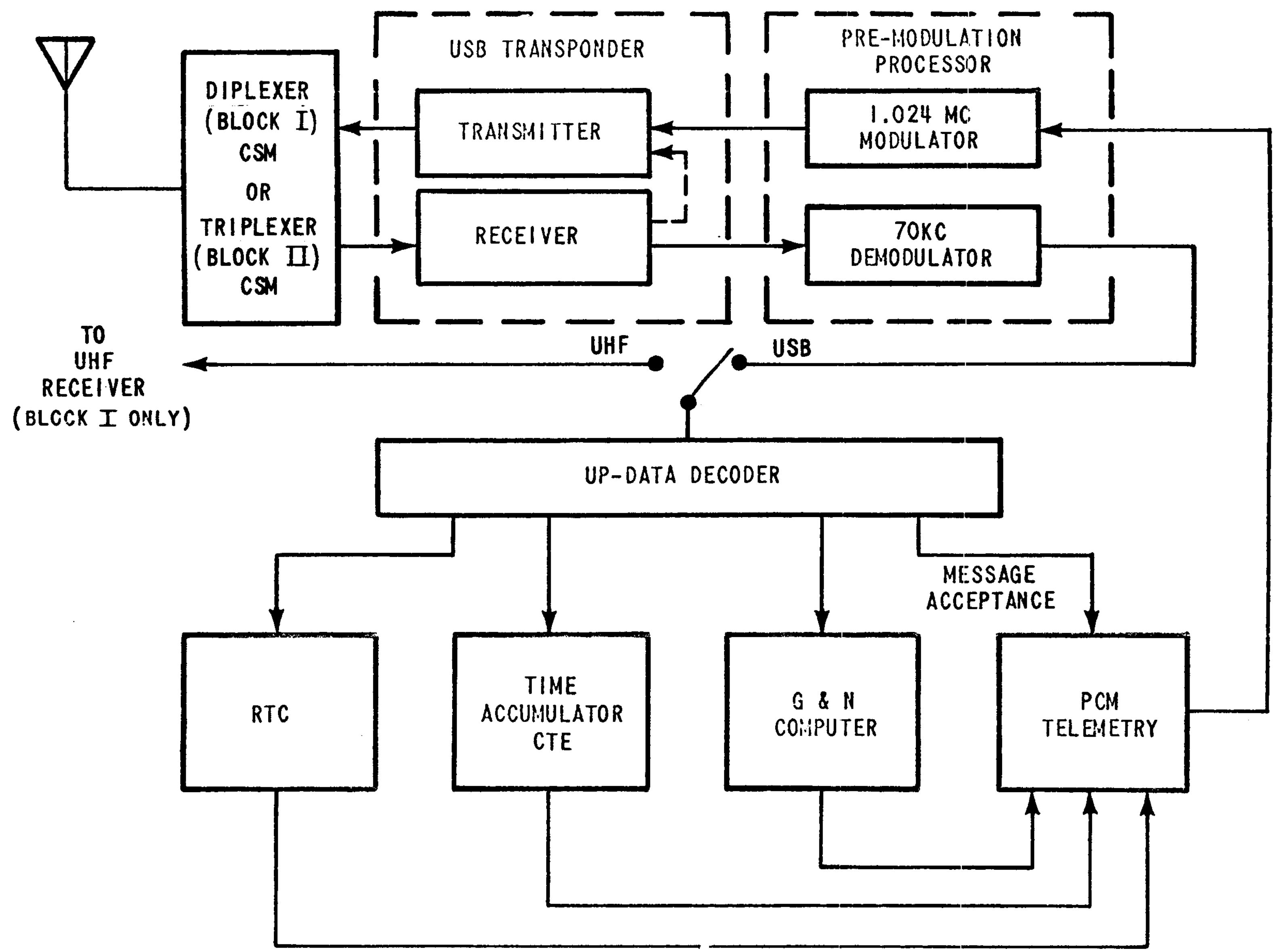

FIGURE 5 - BASIC CSM UP-DATA DETECTION AND DISTRIBUTION

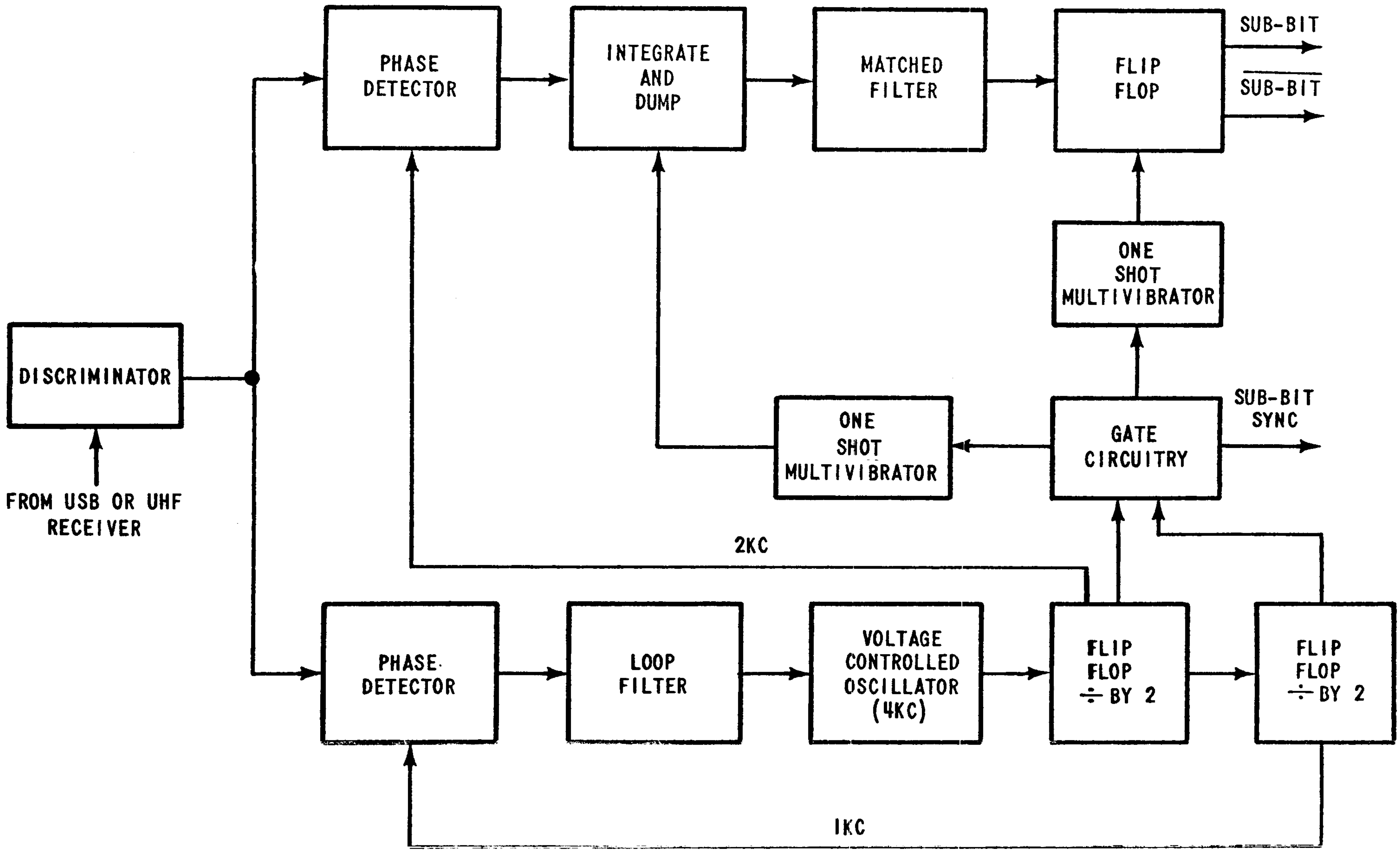

FIGURE 6 BASIC CSM SUB-BIT DETECTION

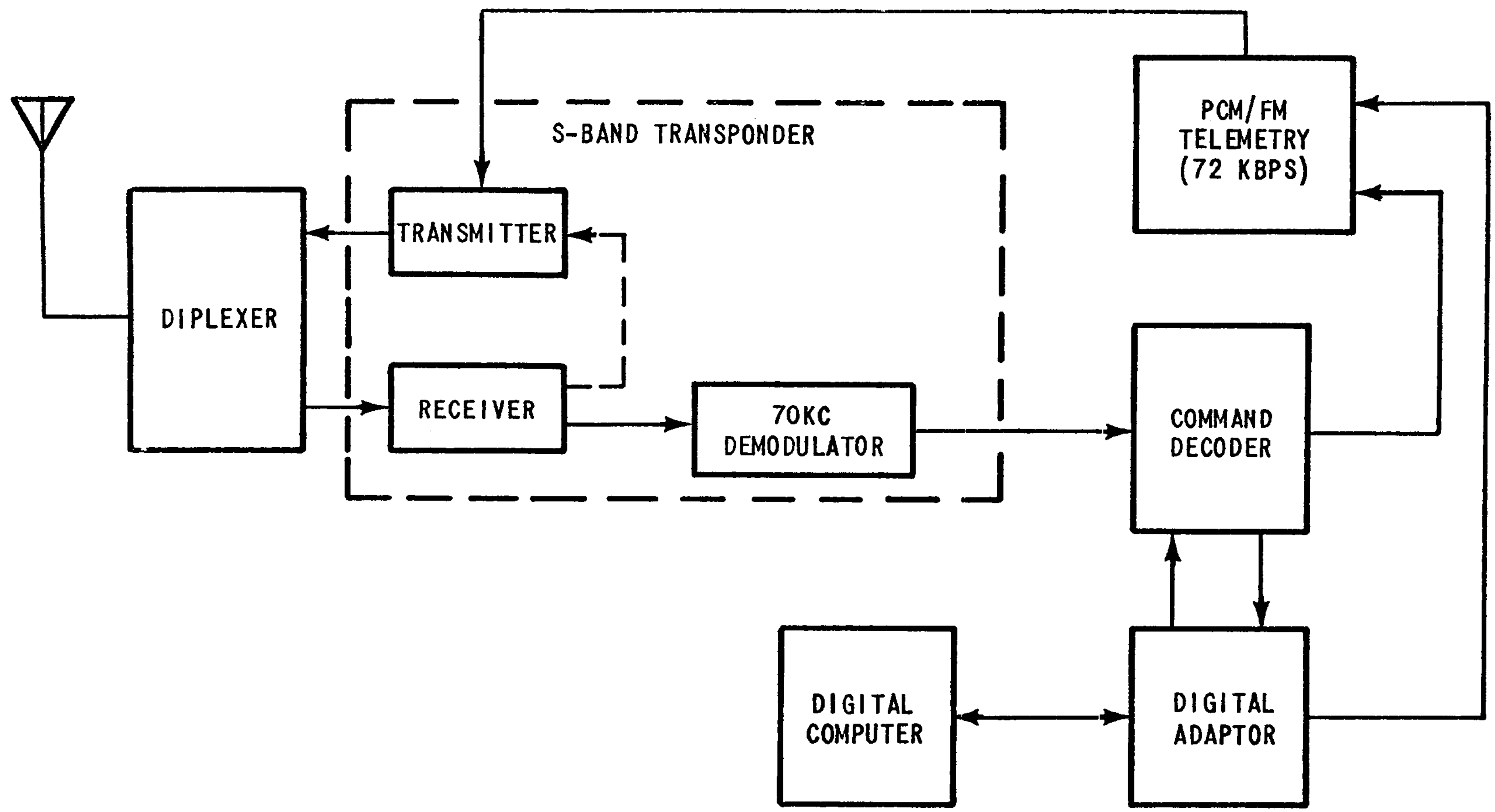

FIGURE 7 - S-IVB/IU UP-DATA DISTRIBUTION (SATURN V)

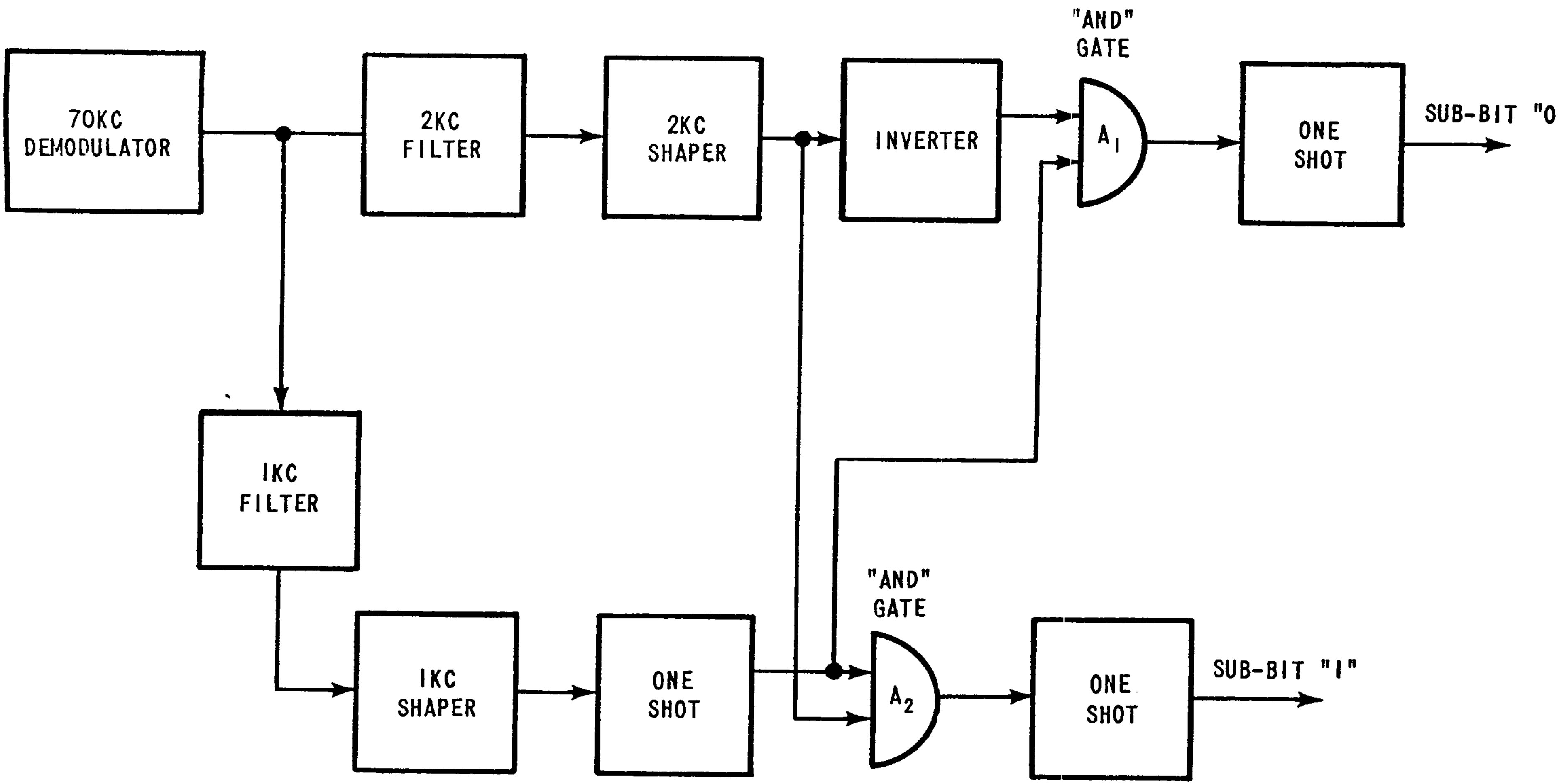

FIGURE 8 BASIC S-IVB/IU SUB-BIT DETECTOR

TABLE I - APOLLO UP-DATA INFORMATION FORMATS (CSM)

REAL TIME COMMANDS

BITS	1 2 3	4 5 6	7 8 9 10 11 12
	VEHICLE ADDRESS	SYSTEM ADDRESS	DATA

APOLLO GUIDANCE COMPUTER

BITS	1 2 3	4 5 6	7	8 9 10 11 12	13 14 15 16 17	18 19 20 21 22
	VA	SA	*	DATA	DATA COMPLEMENT	DATA

* OVERFLOW

CENTRAL TIMING EQUIPMENT

BITS	1 2 3	4 5 6	7 8 9 10 11 12	13 14 15 16 17 18	19-24	25-30
	VA	SA	SECONDS	MINUTES	HOURS 6 BITS	DAYS 6 BITS

TEST MESSAGE

BITS	1 2 3	4 5 6	7 8 9 10 - - - - - - - - - - - - - 30
	VA	SA	TEST MESSAGE (24 BITS)

TABLE 2 - BLOCK I UDL REAL-TIME COMMANDS
(APOLLO S/C 011, 017, AND 020 - UNMANNED CONFIGURATION)

REAL-TIME COMMANDS	FUNCTION
01	Abort Light (System A) - On
00	Abort Light (System A) - Off
07	Abort Light (System B) - On
06	Abort Light (System B) - Off
02	Fuel Cell #1 Purge
03	Fuel Cell #2 Purge
04	Fuel Cell #3 Purge
05	Reset RTC 02-04
10	Lifting Entry
11	Direct Thrust On
12	Direct Thrust Off
13	Reset RTC 10-12
14	+ Pitch Dir. Rot.
15	- Pitch Dir. Rot.
16	+ Yaw Dir. Rot.
17	- Yaw Dir. Rot.
20	+ Roll Dir. Rot.
21	- Roll Dir. Rot.
22	Direct Ullage
23	Reset RTC 14-22
24	Prop. Off SM-A
25	Prop. Off SM-B
26	Prop. Off SM-C
27	Prop. Off SM-D
30	Spare
31	Spare
32	Prop. On SM-A
33	Prop. On SM-B
34	Prop. On SM-C
35	Prop. On SM-D
36	Spare
37	Spare
40	Let Jettison
41	G & N Fail
42	G & N Fail Inhibit
43	Reset RTC 41-42

TABLE 2 - (Continued)

REAL-TIME COMMANDS	FUNCTION
44	Roll Rate Back-up
45	Pitch Rate Back-up
46	Yaw Rate Back-up
47	FDAI Align
50	Reset RTC 44-47
51	-Z Antenna On (VHF SCIN only)
52	+Z Antenna On (VHF SCIN only)
53	G & N Antenna Switching
54	Roll A & C Ch. Disable
55	Roll B & D Ch. Disable
56	Pitch Ch. Disable
57	Yaw Ch. Disable
60	Reset RTC 54-57
61	CM-SM Separation
62	**UDL S-Band Rcvr. Select
63	**UDL UHF Rcvr. Select
64	**H_2 #2 Htr. Fan
65	**O_2 #2 Htr. Fan
66	**H_2 #1 Htr. Fan
67	**O_2 #1 Htr. Fan
70	**Reset RTC 64-67
71	Tower Abort/CSM-SLA Separation
72	Reset RTC 73-77 (73 only for S/C 017 & 020)
73	Spare
74	**C-Band "Off"
75	**C-Band "On", Double Pulse Mode "On"
76	**PCM Low Bit Rate, VHF-FM Transmtr. "Off"
77	**PCM High Bit Rate, VHF-FM Transmtr. "On"

** These Functions are not Implemented on S/C 011.

TABLE 3 - BLOCK I UDL REAL-TIME COMMANDS
(APOLLO S/C 008 AND 012 - MANNED CONFIGURATION)

REAL-TIME COMMANDS	FUNCTION
01	Abort Light "A" On
00	Abort Light "A" Off
07	Abort Light "B" On
06	Abort Light "B" Off
*03	C-Band On, Double Pulse Mode On
*02	C-Band Off
*05	PCM High Bit Rate, VHF-FM Transmitter On
*04	PCM Low Bit Rate, VHF-FM Transmitter Off

*NOT IMPLEMENTED ON S/C 008

TABLE 4 - APOLLO UP-DATA INFORMATION FORMATS (LEM I AND II)

REAL TIME COMMANDS

BITS	1	2	3	4	5	6	7	8	9	10	11	12
	VEHICLE ADDRESS			SYSTEM ADDRESS			DATA					

GUIDANCE AND NAVIGATIONAL COMPUTER

BITS	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
	VA			SA			*	DATA														

* OVERFLOW BIT

PROGRAM READER ASSEMBLY

BITS	1	2	3	4	5	6	7 - - 12	13	14	15	16	17 -- 22
	VA			SA			COMM'D ROUTINE ADDRESS	SEARCH	FWD.	REV.	COMM'D INITIATE	FILLER BITS ALWAYS 0'S

TEST MESSAGE

BITS	1	2	3	4	5	6	7 - - - - - - - - - - - - - - - - 22
	VA			SA			TEST MESSAGE

TABLE 5 - REAL-TIME COMMAND FUNCTIONS

(LEM I AND II)

REAL-TIME COMMANDS	FUNCTIONS
	Three Axis Attitude Controller
00A	Negative Pitch Lo - 5 deg/sec - On
01A	Negative Pitch Lo - 5 deg/sec - Off
02A	Positive Pitch Lo - 5 deg/sec - On
03A	Positive Pitch Lo - 5 deg/sec - Off
04A	Negative Yaw Lo - 5 deg/sec - On
05A	Negative Yaw Lo - 5 deg/sec - Off
06A	Positive Yaw Lo - 5 deg/sec - On
07A	Positive Yaw Lo - 5 deg/sec - Off
10A	Negative Roll Lo - 5 deg/sec - On
11A	Negative Roll Lo - 5 deg/sec - Off
12A	Positive Roll Lo - 5 deg/sec - On
13A	Positive Roll Lo - 5 deg/sec - Off
14A	Descent Helium Regulator #1 SOV Close, Power On
15A	Descent Helium Regulator #1 SOV Close, Power Off
16A	Inverter Select No. 2 (Also Disable No. 1)
17A	EPS Battery #1 HI Volt (Desc.) - Off
20A	S-Band Secondary Transceiver & Power Amplifier - On
21A	S-Band Secondary Transceiver & Power Amplifier - Off
22A	EPS Battery #2 HI Volt (Desc.) - Off
23A	EPS Battery #6 (Asc. - Cdr.) - Off
24A	Primary Water Coolant Valve - Open - Power On
25A	Primary Water Coolant Valve - Open - Power Off
26A	EPS Battery #5 (Asc. - S.E.) - Off
27A	EPS Battery #6 (Tie to S.E. Bus) - On
30A	S-Band Primary Transceiver & Power Amplifier - Off
31A	S-Band Primary Transceiver & Power Amplifier - Enable Prime Control
32A	EPS Battery #3 HI Volt (Desc.) - Off
33A	Spare
34A	Spare
35A	Spare
36A	EPS Battery #5 Tie to CDR. Bus - On
37A	EPS Battery #4 HI Volt (Desc.) - Off

TABLE 5 - (Continued)

REAL-TIME COMMANDS	FUNCTIONS
40A	Spare
41A	Spare
42A	Descent Helium Regulator #2 SOV - Open - Power On
43A	Descent Helium Regulator #2 SOV - Open - Power Off
44A	RCS Main Shut Off Valves - System A - Close - Power On, Inhibit Prime Open Commands
45A	RCS Main Shut Off Valves - System A - Close - Power Off
46A	LEM/SIVB Separation Command Arm
47A	LEM/SIVB Separation Command Arm-Off
50A	RCS Main Shut Off Valves - System A - Open - Power on - Inhibit Prime Close Commands
51A	RCS Main Shut Off Valves - System A - Open - Power Off
52A	C-Band Transponder Off
53A	C-Band Transponder On
54A	RCS Main Shut Off Valves - System B - Close - Power On - Inhibit Prime Open Commands
55A	RCS Main Shut Off Valves - System B - Close - Power Off
56A	Spare
57A	Spare
60A	RCS Main Shut Off Valves - System B - Open - Power On - Inhibit Prime Close Commands
61A	RCS Main Shut Off Valves - System B - Open - Power Off
62A	LEM-SIVB Separation Command Fire
63A	LEM-SIVB Separation Command Fire - Off
64A	Landing Gear Deploy-Fire
65A	Landing Gear Deploy - Off
66A	AGS Status - ASA - Standby/Operate
67A	AGS Status - ASA - Warm up
70A	Abort Stage - Enable
71A	Abort Stage - Disable
72A	AGS Status - AEA - Operate
73A	AGS Status - AEA - Warm-Up/Standby
74A	Ascent Helium Tank Inhibit - Tank #1 Disable
75A	Ascent Helium Tank Inhibit - Tank #2 Disable
76A	Spare
77A	Spare

TABLE 5 - (Continued)

REAL-TIME COMMANDS	FUNCTIONS
00B	Engine Select - Descent Arm On
01B	Engine Select - Descent Arm Off
04B	Landing Radar On, Disable Off
05B	Landing Radar Off
10B	Engine Stop Override - On
11B	Engine Stop Override - Off
14B	Engine Start Override - On
15B	Engine Start Override - Off
20B	On-Board LMP Attitude-Control - Disable
21B	On-Board LMP Translation Control - Disable
24B	Control Mode Select - Enable Attitude Hold, Inhibit Auto
25B	Control Mode Select - Release Auto Inhibit
30B	Control Mode Select - Enable Auto, Inhibit Attitude Hold
31B	Control Mode Select - Release Attitude Hold Inhibit
34B	Prime Relay Master Reset - On
35B	Prime Relay Master Reset - Off
40B	Guidance Control Select - AGS
	Auto Throttle Control - Off
	PRA Select and Stop - On
	Inhibit Auto Engine On
41B	Guidance Control Select - PGNCS
	Auto Throttle Control - On
	PRA Select and Stop - Off
	Remove Auto Engine On Inhibit
44B	Crossover Water Coolant Valve Open - Power On
45B	Crossover Water Coolant Valve Open - Power Off
50B	Glycol Pump Select - Enable No. 2 (Also Disable No. 1)
51B	Glycol Pump Select - Enable #1 (Also Disable #2)
54B	DFI T/M Calibrate On
55B	DFI T/M Calibrate Off, Inhibit Prime Control
60B	X Axis Translation Override On
61B	X Axis Translation Override Off

TABLE 5 - (Continued)

REAL-TIME COMMANDS	FUNCTIONS
64B	ED Battery Activation - Arm
65B	ED Battery Activation - Safe
70B	RCS Helium Pressurization - Fire
71B	RCS Helium Pressurization - Off
74B	Deadband Select - Min
75B	Deadband Select - Enable Prime Control

TABLE 6 - UP-DATA INFORMATION FORMATS (S-IVB/IU)

BITS	FUNCTION
1-3	Vehicle Address
4-6	Decoder Address (DA)
7	Mode Bit
8-9	Interrupt Bits (To Provide Transfer To Subprograms)
10	Sync Bit
11	DA
12	Sync Bit
13-14	Data Bits
15-18	DA
19-24	Data Bits
25	DA
26-30	Data Bits
31-35	DA

TOTAL BITS PER FUNCTION	FUNCTION
3	Vehicle Address
14	Decoder Address
13	Data Bits
2	Sync Bits
2	Interrupt Bits
1	Mode Bit